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Innovative techniques to improve reclamation practices in Alberta oil sands

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Abstract

*Suncor Energy is in the process of reclaiming one of its consolidated tailings ponds (Pond 5). In order to deal with residual soft tailings (aqueous solution of silt, sand, clay and bitumen) still contained within the pond area, a capping and dewatering system is being used. Petroleum coke is used to create the primary, floating trafficability cap, with vertical strip drains then installed to dewater and strengthen the underlying tailings. As these tailings dewater, additional loading is required in order to ensure dewatering of the top of the tailings column under the cap. This loading is to be accomplished through the placement of a layer of tailings sand on top of the coke. The need for a temporary reclamation cover over tailings sand has been identified to stabilise the sand against water and wind erosion prior to the final reclamation cover being established. A peat/mineral amendment is usually used to mitigate poor water retention in the sand, but rather than using stockpiled cover soil in the establishment of the temporary cover (and potentially lost to future use), an alternative amendment was desired. Barley (*Hordeum vulgare*), an annual species has been the cover crop of choice for years. To evaluate the possibility of establishing a temporary reclamation cover on tailings sand, a program was initiated to identify appropriate grass species, and to evaluate the use of alfalfa pellets (*Medicago sativa*) as an amendment. It is proposed that alfalfa pellets may improve soil structure and moisture storage, and serve as a slow release fertiliser providing nutrition to plants. This study screens a series of native grasses [fringed brome grass (*Bromus ciliatus*), June grass (*Koeleria macrantha*), a mix of native grasses along with barley and oats (*Avena sativa*) for suitability to grow and stabilise tailing sands. First year observations showed remarkable growth of native species on tailings sand. Plant height, plant cover and total nitrogen were similar across the tested alfalfa pellets application rates of 5, 10 and 20 t/ha. Despite the shorter plant height and lower vigour of the fringed brome grass and June grass compared to barley and oats, the native grasses exhibited greater nitrogen (N) uptake, which may be explained by extensive root growth and development. Additionally, the perennial native grasses have potential to provide adequate cover against erosion for a longer portion of the year and in subsequent years. The application of alfalfa pellets at the rate of 5 t/ha improved moisture retention and bulk density, but to a lesser extent than at 20 t/ha. Experimental plots will be monitored in 2011 to quantify residual N in soils that could be potentially available to plants. Generally, study results suggest the studied native species can be used to stabilise tailings sand against water and wind erosion.*

1 Introduction

This study evaluates the use of cover crops to stabilise tailings sand against water and wind erosion on a temporary reclamation area on Pond 5 (Figure 1). Tailings sand exhibits low moisture retention, lacks organic matter and nutrients, and has poor structure. To evaluate the possibility of establishing a temporary reclamation cover on tailings sand, a program was initiated to identify appropriate grass species, and to evaluate the use of alfalfa (*Medicago sativa)* pellets as an amendment. It is hypothesised that alfalfa pellets may improve soil structure and moisture storage, and serve as a slow release fertiliser providing nutrition to plants. This study screens a series of native grasses [fringe brome grass (*Bromus ciliatus*), June grass (*Koeleria macrantha*), a mix of native grasses along with barley (*Hordeum vulgare*) and oats (*Avena sativa*) for suitability to grow and stabilise tailing sands. The native grass seed mixture is comprised of Canada wild rye (*Elymus canadensis*), Rocky Mountain fescue (*Festuca saximontana*), spike trisetum (*Trisetum* *spicatum*), tufted hair grass (*Deschampsia cespitosa*), slender wheatgrass (*Elymus trachycaulus*), fringe brome grass, June grass and oats. The native plants chosen for this study were based on their ability for a quick establishment and perceived ability to thrive in droughty and nutrient poor conditions. Specific objectives are to:

- Test efficacy of Western Alfalfa Milling's Alfalfa pellets to improve soil structure and moisture retention.
- Determine if additional fertilisation is required to stimulate rapid plant growth on tailings.
- Test if alfalfa pellets can serve as slow release fertiliser product providing nutrients to plants.
- Quantify fertiliser efficiency defined as the proportion of applied fertiliser that is recovered in plants.

Figure 1 Study location on Suncor Pond 5

2 Methodology

2.1 Site characteristics

The study is located on a 1 ha tailings sand pad constructed on SW corner of Pond 5 (Figure 1) at the Suncor Energy site at Fort McMurray, Alberta. A capping and dewatering system is being used to deal with residual soft tailings still contained within the pond. Petroleum coke is used to create the primary, floating trafficability cap. Vertical strip drains are then installed to dewater and strengthen the underlying tailings. As these tailings dewater, additional loading will be required in order to ensure dewatering of the top of the tailings column under the cap. This loading is to be accomplished through the placement of a layer of tailings sand on top of the coke.

Soil samples were collected for initial site characterisation prior to seeding. Initial soil total organic matter content ranged from 0.12 to 0.38 %. Electrical conductivity averaged 2 dSm^{-1} and pH ranges from 7.18 to 7.35. Soil bulk density ranges from 1.4 to 1.8 g/cm^3. Available nitrogen (N) and phosphorus (P) were less than 2 mg/kg, potassium (K) was less than 10 mg/kg and sulphur (S) varied from 1,490 to 1,680 mg/kg.

Micronutrients were less than 1 mg/kg for copper (Cu); and ranges from 3.8 to 6.2 mg/kg for iron (Fe); 0.52 to 0.9 mg/kg for manganese (Mn) and from 0.21 to 0.29 mg/kg for zinc (Zn).

2.2 Experimental design

A split-split plot design was used for the study, which tested grass species at 5 levels (barley, oats, June grass, fringed brome grass and a native seed mix), fertiliser rates at 2 levels (50 and 250 kg N/ha) and alfalfa pellets at 3 levels (5, 10, and 20 t/ha) on growth (plant vigour, plant height and biomass production) and nutrition. Alfalfa pellets, grass species and fertiliser rates represent main, sub-plot and sub-sub-plot treatments, respectively. The study was replicated in three blocks, with each block being 100 x 20 m. A 2 m buffer strip separates each block. The alfalfa pellets, main plot treatments were broadcast using a John Deere tractor, PTO and three point hitch attached to a PTO driven fertiliser spreader. The pellets were incorporated into the tailings sand using a PTO driven, 2-metre wide Howard rotovator at 30 cm depth. The species, sub-plot treatments were randomly assigned within each block. Seeding was completed in the second week of July, 2010 using a seed drill (Fabro Plot Seeder, Swift Machines Ltd), consisting of 10 drills at 20 cm row spacing for a 2 m wide seeding. The seeder had depth bands to control seeding depth. A seeding rate of 50 kg/ha was used. Table 1 illustrates the composition of the native seed mix.

Table 1 Custom reclamation seed mix for Pond 5

Species	Percent of Seed Mix
Elymus trachycaulus (“Adanac” slender wheatgrass)	16.9
Elymus canadensis (“ARC Centennial” Canada wild rye grass)	4.4
Festuca saximontana (Rocky Mountain fescue)	13.8
Trisetum spicatum (Spike trisetum)	7.5
Bromus ciliatus (Fringed brome grass [33 % coating])	9.3
Koeleria macrantha (June grass [50 % coating])	4.4
Deschampsia cespitosa (“Nortran” tufted hair grass)	6.2
Avena sativa (Oats)	37.5

Fertiliser rate, sub-sub-plot treatment, was applied using a quad fertiliser spreader. Bulk density measurements were adapted from Blake and Hartge (1986). Bulk density samples were collected before seeding and again at harvest. Three bulk density samples of about the same size were randomly collected from each pellet level and fertiliser treatment within each replicate, which were taken to Alberta Innovates Technology Futures (AITF) laboratory for bulk density measurements. Soil samples 0–30 cm depth, within each plot and from an area outside were collected and sent to ALS laboratory (Saskatoon) for available nitrogen determination. Twenty randomly selected samples were further analysed for salinity content. Tissue samples (roots and shoots) were collected from each species within each plot for total nitrogen determination (Leco method) by ALS laboratories. Precipitation, mainly rainfall data was collected from Suncor Energy local weather station. This weather data was compared to climate normals for temperature and precipitation at Fort McMurray.

3 Data collected and analysis

Soil bulk density, plant vigour, percent of plot cover by plants, plant height and total available N in the roots and shoots of the plants were normalised using a square-root transformation. Nitrogen efficiency was computed based on assumption that N contribution from pellets to plant uptake is negligible. Statistical analyses were conducted using SAS release 9.2 for Windows XP (SAS Institute Inc., Cary, NC, 2009). SAS MIXED procedure was used to analyse the data. If the model revealed statistical significance ($p \leq 0.05$), Tukey-Kramer adjusted comparisons were used to rank significant means.

4 Results

The native species showed remarkable growth performance in tailings sand in the first year after establishment (Figure 2). Fertiliser rate and species significantly affected plant vigour. Alfalfa pellet effects were non-significant. Generally, there were no significant interaction effects. Plant vigour was significantly greater when fertilised at 50 kg/ha than at 250 kg/ha. Potential plant injury from the higher fertiliser rate may partly explain reduced vigour. Fringed brome grass had significantly less vigour than barley, June grass, native mix and oats. Additionally, June grass exhibited significantly less vigour than the native mix.

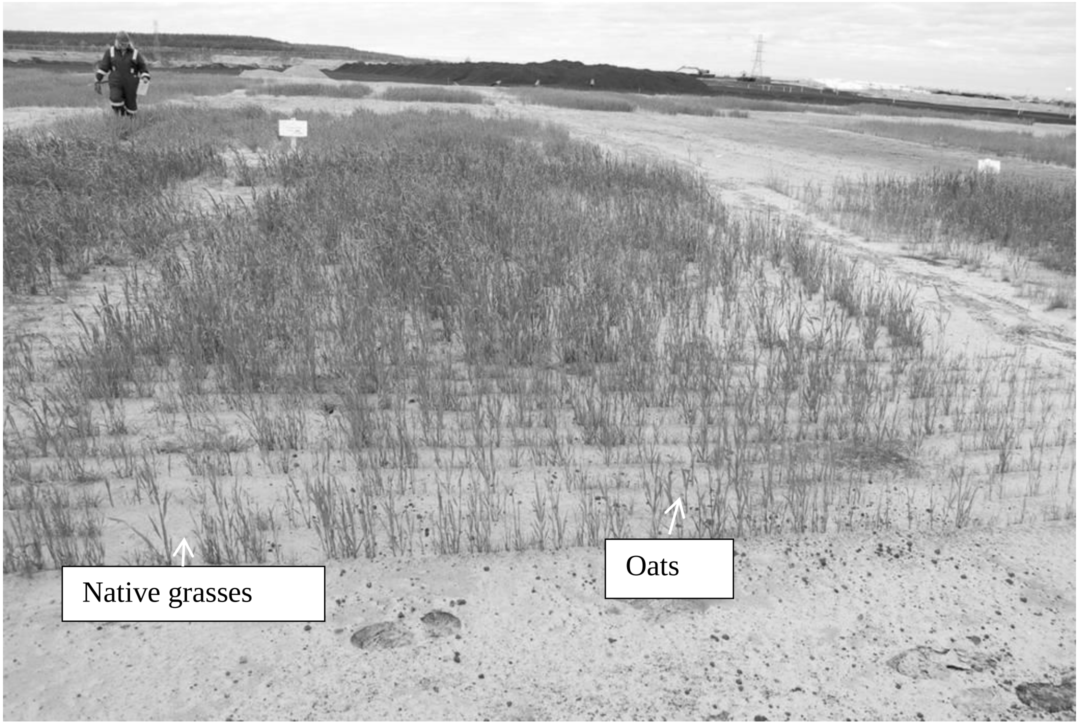

Figure 2 Growth of native species on tailings sand

Fertiliser rate, species, as well as the interactions of fertiliser rate by alfalfa pellets and fertiliser rate by species significantly affected plant height. Plants fertilised at 50 kg N/ha were taller than those fertilised at 250 kg N/ha. The one-time application of fertiliser at 250 kg N/ha may have been too heavy and fertiliser volatilisation may have resulted in heat injury. Split application could improve uptake and minimise potential leaching losses to the environment. Additionally, the native grasses were slow in emerging from the ground and may have also suffered heat injury. Barley and oats germinated in about 7 to 10 days whereas the native grasses took about 21 days to germinate.

Fringed brome grass (4 cm) and June grass (4 cm) recorded significantly lower plant heights than barley (45 cm), native mix (35 cm) and oats (45 cm). Similarly, barley and oats had significantly higher plant heights than native mix. There was no significant difference between barley and oats in terms of plant height. The native grasses were slower to emerge and generally smaller by nature compared to the oats and barley hence differences in height was expected.

Table 2 Main effects of fertiliser on growth and nutrient status of plants

Variable	Fertiliser Application Rate (kg N/ha) Mean (SD)	
	50	250
Vigour	2.11 (1.18)	1.51 (1.04)
Cover (%)	49.91 (34.73)	38.87 (29.69)
Height (cm)	29.32 (21.55)	24.93 (17.92)
Total available N in soil (mg/kg)	14.10 (17.62)	5.83 (3.32)
Shoot total N (%)	2.22 (0.79)	2.37 (0.61)
Root total N (%)	1.18 (0.48)	1.08 (0.35)

NB: n = 45 for statistical analysis.

There were no significant differences in plant heights for species at the different pellet applications rates of 5, 10 and 20 t/ha. Total available N did not differ between rates of alfalfa pellet applications or between fertiliser rates. Total N uptake was similar between species and in roots and shoots. Despite the shorter plant height and lower vigour of the fringed brome grass and June grass compared to barley and oats, the native grasses exhibited greater N uptake. Furthermore, the native grasses are perennial and have potential to provide adequate cover against erosion for a longer portion of the year and in subsequent years. The application of alfalfa pellets at 5 t/ha improved bulk density (1.54 g/cm^3) of tailing sands, but to a lesser extent than at 20 t/ha (1.4 g/cm^3) compared to no pellets (1.67 g/cm^3). Alfalfa pellets incorporated into the tailings sand improved moisture retention. The short growing season (less than 3 months) did not allow full realisation of the benefits of the alfalfa pellets and fertiliser application. While both barley and oats had higher plant heights, it is interesting to note that the native grasses developed a deeper and more extensive root system (Figure 3) that may be more suitable in drier environments such as the tailings sand, where moisture can be critical for plant survival and growth.

Table 3 Main effects of alfalfa pellet application on overall growth and nutrient status of plants

Variable	Alfalfa Pellets Application Rate (t/ha)		
	5	10	20
	Mean (SD)	Mean (SD)	Mean (SD)
Vigour	1.88 (1.35)	1.85 (1.09)	1.70 (0.99)
Cover (%)	43.93 (33.17)	45.03 (32.56)	44.20 (33.19)
Height (cm)	27.76 (20.73)	27.41 (20.79)	26.20 (18.53)
Total available N in soil (mg/kg)	5.21 (3.52)	7.77 (8.17)	16.91 (19.58)
Shoot total N (%)	1.99 (0.74)	2.30 (0.58)	2.61 (0.68)
Root total N (%)	1.05 (0.46)	1.08 (0.45)	1.25 (0.32)

NB: SD = standard deviation, total samples for statistical analysis (n) = 30.

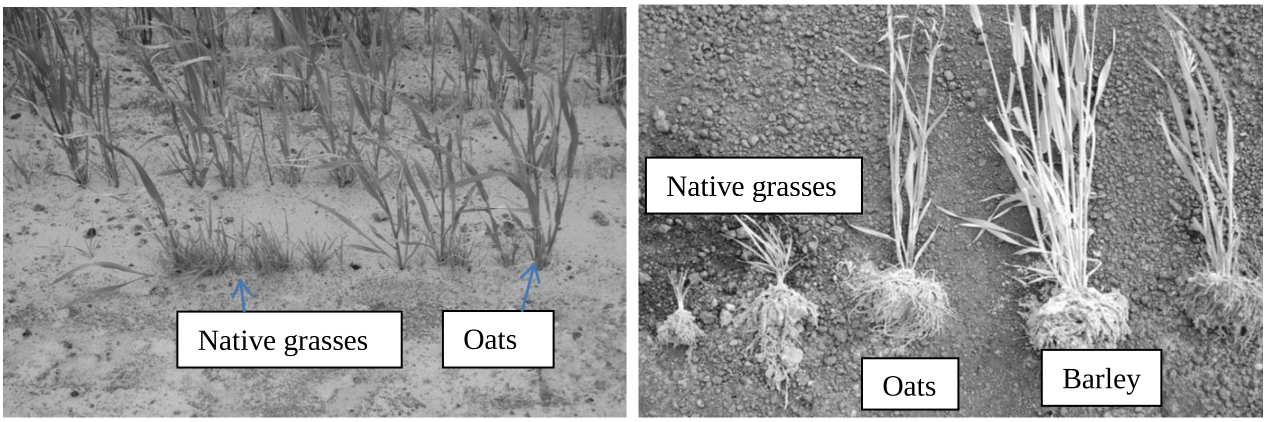

Figure 3 Growth comparison of the native grasses in relation to oats and barley plants in the native seed mix at harvest time. Note: greater rooting depth and mass of the native grasses compared to oats and barley

Table 4 shows N use efficiency data for barley and oats under different fertiliser regimes. Nitrogen uptake efficiency was low and ranged between about 3 to 8% (Table 4) suggesting greater nutrient supply does not necessarily lead to more N uptake. Un-accounted N may be lost to the environment or retained in soil. June grass, fringed brome grass and the native mix were not harvested as the plants were too small.

Although alfalfa pellets appeared to have been decomposed, perhaps contribute less nutrients for plant uptake suggested by negative efficiency values in Table 4. Presumably, nutrients may still be tied-up (only a small percent mineralised) and potentially available to plants next season. The potential for N loss is influenced primarily by weather conditions such as rainfall, sunshine, and temperature (Jones et al., 2009). Rainfall during the month of August following the application of fertiliser averaged 111 mm versus 72 mm from long term data (Environment Canada, 2010). The deeper rooting depth and root development of the native species may prove to be a better adaptation to tap into underground moisture and nutrients.

Table 4 Nitrogen use efficiency for barley and oats under different nutrient regimes

Species	Fertiliser(kg/ha)				Un-accounted N (kg/ha) (Applied-total)	N uptake efficiency (% of applied)
	Applied	Recovered				
		Soil	Plant	Total (plant + soil)		
Barley	50	11.95	33.47	13.94	36.06	3.98
Oats	50	9.79	29.82	11.63	38.37	3.68
Barley	50	8.86	26.76	10.47	39.53	3.22
Oats	50	20.68	60.45	24.29	25.71	7.23
Barley	50	64.74	28.62	66.47	-16.47	3.46
Oats	50	7.02	37.34	59.19	-9.19	4.37
Barley	250	10.87	9.33	12.70	237.30	2.27
Oats	250	22.83	15.67	20.36	229.64	3.80
Barley	250	14.77	23.19	36.40	213.60	5.43
Oats	250	13.06	19.37	27.15	222.85	4.95
Barley	250	15.45	33.21	33.16	216.84	8.04
Oats	250	7.02	14.56	24.27	225.73	3.53

5 Conclusions

The growing season was too short to realise the full benefits from the alfalfa pellets and fertiliser application. Adequate rainfall in the months following seeding aided in the successful establishment of the plots. It appears that alfalfa pellets at 5 t/ha and a fertiliser rate of 50 kg/ha offered the best potential for growth performance on tailings sand. An optimal N utilisation is necessary to improve plant growth, improve uptake efficiency and minimise N loss, which reduces the risk of environmental pollution via leaching into water aquifers. The species varied in their uptake of N and native perennials such as those used in this study are known to use less N than cultivated crops. Current fertiliser and alfalfa pellets rates needs to be refined to optimise plant nutrient uptake. Both oats and barley are annual crops and necessitate re-planting annually to continue to provide erosion control. By contrast, the native perennial grasses can provide protective cover and keep the reclaimed land green for several years. It will be interesting to see how well the native species survive the winter conditions and perform in the following year.

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